



BEHAVIOR OF GRANULAR MATERIALS IN MICROGRAVITY AT VERY LOW EFFECTIVE STRESSES

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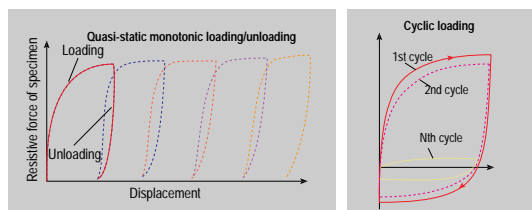


Science

Objectives

- What is the constitutive behavior of cohesionless granular material at very low confining pressures (effective stresses) not achievable in a 1-g terrestrial environment?
- Will cohesionless granular materials under low confining pressures dilate or contract if subjected to a compressive load regardless of the initial relative density?
- What is the influence of particle interlocking and other fabric properties on the shape of the Mohr-Coulomb envelope near the mean effective stress space origin?
- Will strain-softening and associated instability phenomena, such as localization of deformation in shear bands, occur before or after peak deformation resistance, either because the material has reached a peak strength or a bifurcation point?
- Will the critical void ratio of cohesionless granular materials, under very low confining pressures, approach the maximum void ratio at which the material deforms indefinitely without changes in its internal stress state and volumetric strain?

Hardware & Method



Nine displacement-controlled compression tests performed on dry Ottawa F-75 banding sand in three series at 0.05, 0.52, and 1.3 kPa confining pressures.

F1: Three dense specimens, quasi-static loading/unloading (STS-79, September 1996)

F2: Three loose specimens, quasi-static loading/unloading (STS-89, January 1998)

F3: Three loose specimens, cyclic loading (STS-89, January 1998)

Test cell Locker 1: Computer, control systems Locker 2: Viewing stage, fluid lines, cameras



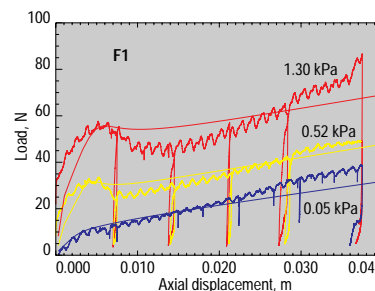
Test cells comprise sand specimens contained in a latex membrane (with a grid pattern for CCD cameras) between metal end platens and housed in a water-filled Lexan jacket. The test cells and experiment systems are carried aboard the Space Shuttle.

Space Sciences Laboratory — EST-1, Marshall Space Flight Center/Huntsville, AL 35812, June 10, 1998

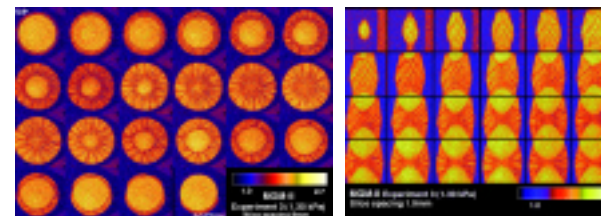
Results & Analysis

Post-flight analyses

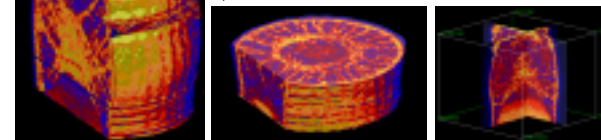
- Laser profiles of the specimens at 5 deg. intervals.
- Impregnate specimens with epoxy resin to stabilize internal fabric.
- CT scans to map density and build 3-D models of interior.
- Physically slice specimens and prepare thin sections for examination under optical microscope.
- Digitize in-flight video images to map volume and shape changes vs. time.



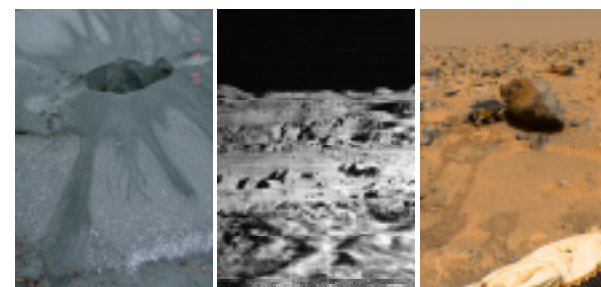
Nonlinear 3D finite element analysis was conducted on the specimen-membrane-end platen system (after B. Jeremic, "Finite Deformation Hyperelasto-Plasticity of Geomaterials," Doctoral dissertation, University of Colorado at Boulder, 1997). The correspondence between the experiments and the analyses, using a consistent set of material parameters from separate experiments, show that the findings are reasonable and show internal consistency (after Sture et al., "Mechanics of Granular Materials at Low Effective Stresses," submitted to ASCE Journal of Aerospace Engineering)



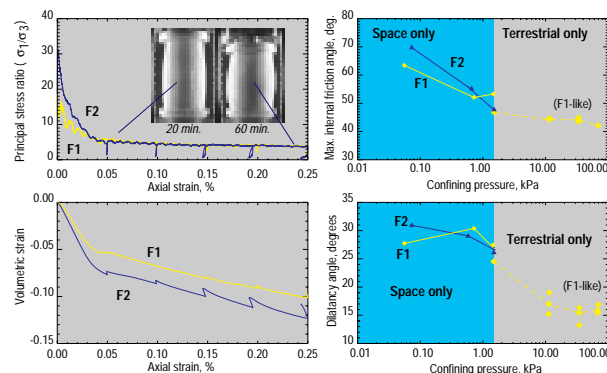
Computed tomography (CT) images of resin-impregnated MGM specimens (above), are assembled to provide 3-D volume renderings (below) of density patterns formed by diffused bifurcation under the external loading stress profile applied during the experiments.



Potential Applications



Soil mechanics and geotechnical engineering Mining engineering
Coastal and off-shore engineering Earthquake engineering
Powder technology Terrestrial and planetary geology
Erosion processes Off-road and planetary vehicle engineering



Load and volume behavior of sand at 85% (F1) and 65% (F2) relative density tested at 0.05 kPa.

Increase in confining pressure results in a decrease in friction and dilatancy angles.